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The Parasitism of *Colletotrichum Lagenarium* (Pass.) Ell. and Halst.

By Duke V. Layton

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
AND MECHANIC ARTS
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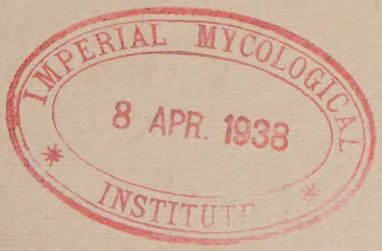

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SUMMARY

A technique for inoculating and measuring the relative resistance to *Colletotrichum lagenarium* of cucurbits is described.

Typical symptoms of anthracnose are given for the more common hosts, and symptoms are briefly described for each new host. Symptoms of anthracnose on cantaloupe are contrasted with symptoms of other cantaloupe leaf spot diseases. A previously unrecorded symptom is reported for watermelon on the runners near the crowns of the plants.

Temperatures of 15° to 17° C. or less during the 14-16-hour period in the moist chamber resulted in no infection. Within the temperature range (20-30° C.) infection takes place. The manifestation of symptoms is retarded 24 hours by lowering the temperature 10° C.

The host range of *C. lagenarium* has been extended to include the following susceptible cucurbits: *Apodanthera undulata, Cucurbita foetidissima, C. texana, Ibervillia tenuisecta, Luffa* sp., and *Sicyos parviflorus.*

From the standpoint of relative resistance, the genus Cucurbita may be said to be the most resistant genus studied, while Cucumis and Citrullus are the most susceptible.

Slight differences in resistance and susceptibility were found in commercial watermelon, cantaloupe and cucumber varieties, but in no case was the resistance sufficient to be of commercial importance.

The comparative resistance or susceptibility is given for the following cucurbits:

Watermelon

71 Commercial American varieties (163 seed lots).
6 Citron varieties.
165 Foreign varieties from 15 countries.
407 Kleckley Sweet selections.
187 Conqueror selections.

Cantaloupe

32 Commercial American varieties.
26 Foreign varieties from five countries.
81 Selections.

Cucumber

18 Commercial varieties.

Cucurbita spp.

21 Commercial varieties.

Three edible, non-commercial African watermelon varieties were found which were highly resistant to anthracnose but susceptible to wilt. Crosses of these varieties, Africa 8, Africa 9 and Africa 13 were made on Iowa Belle, Iowa King and a few miscellaneous watermelon varieties. Resistance to anthracnose was dominant to susceptibility and segregation in the F_2 and in the F_1 backcross generation proved that only a single factor pair for resistance and susceptibility was involved. From these crosses strains of watermelon have been developed which are resistant to anthracnose and wilt.

The Parasitism of *Colletotrichum Lagenarium* (Pass.) Ell. and Halst.[1]

By DUKE V. LAYTON[2]

Colletotrichum lagenarium, the fungus which causes anthracnose of cucurbits, is the most widespread of the many fungous parasites which attack this family of plants. Its world-wide distribution, its annual occurrence on watermelons, cantaloupes, cucumbers and gourds, and its destructiveness all contribute to its economic significance. Walker and Weber (24) indicate its seriousness on watermelon in the southern United States, while in Iowa, Gilman and Porter (7) considered it the most serious disease of watermelon. They reported a 15 percent loss caused by anthracnose in 1924, 25 percent in 1925 and 26 percent in 1926. In some localities this disease caused a total loss of the crop in 1926. Each year fields like the one shown in fig. 1 are present in the state.

Since 1925 a watermelon breeding program has been carried on by the Botany and Plant Pathology Section of the Iowa Agricultural Experiment Station with particular emphasis on the development of varieties resistant to wilt. This program with its numerous strains of melons collected from widespread localities, coupled with the many genetic segregates resulting from hybridization and selection, offered an unparalleled opportunity to investigate resistance and susceptibility to anthracnose among these strains. But to take advantage of this opportunity, the development of a technique for comparative testing of anthracnose resistance was necessary.

This paper reports: (1) The development of this technique by means of a study of the pathogenicity of *Colletotrichum lagenarium* and the factors favoring its infection under field and greenhouse conditions; (2) the comparative resistance to anthracnose of the watermelons, cantaloupes, cucumbers and other Cucurbitaceae available; (3) the finding of a resistant non-commercial melon; (4) its use as a parent for the production of a

[1]Taken from a thesis submitted to the faculty of the Graduate College, Iowa State College, in partial fulfillment of the requirements for the degree of doctor of philosophy. Project No. 70 of the Iowa Agricultural Experiment Station.

[2]The writer wishes to express his sincere appreciation to Dr. J. C. Gilman, Dr. I. E. Melhus and Dr. C. S. Reddy, under whose supervision this investigation has been conducted, for their valuable suggestions and criticisms in the preparation of the manuscript.

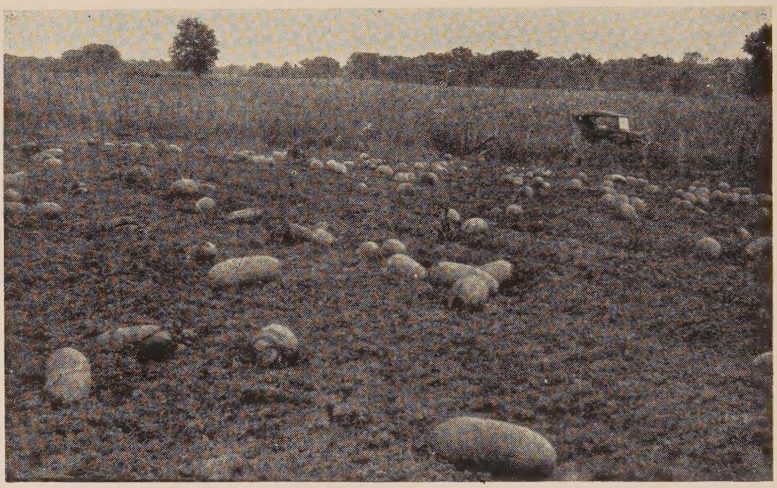

Fig. 1. Anthracnose of watermelon. Complete defoliation of the plants in this commercial watermelon field, caused by *Colletotrichum lagenarium* under natural conditions.

commercial type and (5) the genetic behavior of watermelons resistant and susceptible to anthracnose. Results given in this paper were obtained in the greenhouse and field and extended over a 6-year period.

LITERATURE REVIEW

Although anthracnose has been known on cucurbits since first reported by Passerini in 1867, the literature has been so well brought together and reviewed by Gardner (6) that it is unnecessary to repeat his review of the earlier work. Therefore, only the papers published since Gardner's review are discussed.

Gardner (6), in addition to an excellent review of literature, gave a comprehensive account of the biology of the fungus, its method of penetration into the host and the relation of environmental conditions to disease. His investigations were carried out both in the greenhouse and in the field. Dissemination, overwintering and nutritional requirements of the parasite as well as control measures were investigated. While Gardner's work was primarily on anthracnose of cucumber, he gives a rather complete report on most phases of the problem for cucurbits in general.

Since Gardner's paper, the chief advances in our knowledge of anthracnose have been in the mycological field. Rodigin (16) in 1928 reported extensive studies on the nutrition and appresoria formation of the fungus. He considered that growth was

more nearly normal on natural substrata than on artificial media. In 1930 he discussed anthracnose of pumpkins and reported that the organism was transmitted by the insect *Pimelia* sp. and by the wind and overwintered on host residue.

Göllner (8), working in Hungary on melon anthracnose, was unable to find pycnidia or sclerotia as was reported by Rodigin, but later he described a modification of the acervulus which he termed a pseudopycnidium on melons with thick cuticle. His findings on temperature effects will be discussed with the findings reported herein.

Stevens (23) in 1931 reported the finding of the ascigerous stage (*Glomerella lagenarium*) in cultures which had been irradiated with ultra-violet light.

MATERIALS AND METHODS

Cultures of *Colletotrichum lagenarium* used in these studies were isolated from specimens of watermelon anthracnose collected by the writer in 1929 near Muscatine, Iowa, and sent to Dr. F. L. Stevens of the University of Illinois. In the winter of 1930, when the study of the anthracnose organism was initiated, transfers from the cultures isolated from the Iowa material were obtained from Dr. Stevens.

Seed of the various genera, species, varieties and selections of the Cucurbitaceae were obtained from seed stores, growers, workers in institutions in this country and abroad and from the Division of Foreign Plant Introduction, Bureau of Plant Industry, Washington, D. C. Several thousand selections of seed were available from the watermelon wilt project carried on since 1925 by the Iowa Agricultural Experiment Station.

In determining the reaction to anthracnose the plants were grown in duplicate pots and the experiment was repeated at least once. The plants were grown for inoculation in the greenhouse in 4 or 5-inch pots. Five seeds of each sort with a like number of a standard susceptible check, commercial Kleckley Sweet, were planted in opposite halves of the same pot. Pots and soil were steam sterilized before planting to prevent wilt and damping-off.

Inoculations were made with suspensions of spores obtained from cultures of *C. lagenarium* growing on watermelon rinds or from plants that had been killed by the organism. Plants were inoculated by spraying with the spore suspension. Inoculated plants were then placed in a moist chamber for 14 hours and subsequently held under ordinary greenhouse conditions until symptoms of anthracnose developed. Symptoms appeared 3 to 6 days after inoculation, and usually the first reading of infection was made on the fifth day and the final

reading on the eighth day. In all cases resistance or susceptibility was compared with that of Kleckley Sweet.

The type of lesion which developed near the ground line on the hypocotyl served as a convenient criterion for classifying plants as either susceptible or resistant. With susceptible varieties large sunken lesions soon killed the plants. With resistant varieties small lesions appeared but apparently resulted in little injury to the plant.

Reaction of Kleckley Sweet and other similarly susceptible varieties was considered as the norm, and "N" was used to record this reaction. A reaction more susceptible than the norm was recorded as "S" and more resistant as "R." A plus sign after either of these symbols designated a greater degree of susceptibility or resistance. A brief description of the types of infection and the symbols used for their indication are given below:

S + Very susceptible. Plants died very quickly.
Example, India 17.

S Slightly more susceptible than Kleckley Sweet.
Example, Chilian.

N Conspicuous sunken hypocotyl lesions. Plants killed 5 days after inoculation.
Example, Kleckley Sweet.

R Less susceptible than Kleckley Sweet. Plants killed 6 to 8 days after inoculation.
Example, Ice Cream.

R + Small lesions resembling mechanical wounds. Little or no injury. Plants live.
Example, Africa 8.

Plants marked "S +" and "S" are noticeably more susceptible than those marked "N" and can be detected under field conditions as well as in the greenhouse. Those designated by "R" are only slightly more resistant than "N," the difference being that 1 to 3 days longer are required for such plants to die in the greenhouse. This degree of difference is not always sufficient to show a distinction between these classes in the field. The reaction of "R +" represents the only significant resistant reaction either under greenhouse or field conditions as the plants develop only slight symptoms and continue to grow unharmed. From a practical standpoint or from the standpoint of breeding, plants showing a reaction of "R +" are the only ones usable for the development of resistant strains.

SYMPTOMS

Symptoms of anthracnose are confined to that portion of the plant which is above the ground. In the greenhouse the characteristic symptoms of the disease on the leaves of all hosts studied are irregular yellowish brown, dark brown to almost black spots. Size of the spots will vary, depending upon the

susceptibility of the host. With pumpkin the spots are very small and inconspicuous, and with lagenarium gourd they are very large. In contrast to the restricted spots on pumpkin, lesions on the leaves of watermelon in the greenhouse are numerous, enlarge rapidly and quickly destroy the leaf. With most hosts the brown area of the leaf spot is surrounded by a yellowish, translucent or water-soaked border. On stems, damping-off is a conspicuous greenhouse symptom of anthracnose in hosts readily attacked by the organism.

In the field the first anthracnose symptoms on watermelon (in contrast to greenhouse conditions) are small, raised, water-soaked areas located along the vines near the crown of the plant. These early symptoms seem not to have been described by previous workers. The small, raised, water-soaked areas will appear near the crown on the vines even before leaf spot appears on the crown leaves. The spots may be found on plants soon after they have begun to vine, and later they will be observed to extend further toward the tip of the vine. Later these spots become sunken and spores are produced.

Irregular spots appear on the leaves near the center of the plant. These spots usually appear first in midsummer during hot, dry weather. Conditions not being favorable for the spread of the fungus, these leaves may remain alive for a considerable time. Later in the season when there is an abundance of moisture, the fungus will spread rapidly, killing all of the leaves near the crown. The organism sporulates abundantly on these infected leaves, providing spores for its spread. At this stage of development of the disease, the bare green vines near the crown of the plants are particularly conspicuous and the only green leaves which may be present late in the season are the ones near the tips of the vines.

Two general types of lesions occur on the watermelon fruit. Small, raised, water-soaked spots (fig. 2) may become evident over the entire exposed surface of the melon. These spots usually do not appear until the melons are in the later stages of development. On melons that ripen before the rainy season approaches, these spots do not enlarge or become sunken. The other type of lesion becomes sunken, sometimes cracked, and bears masses of pink spores (fig. 3). These spots are most numerous on the sides of the melon near the ground (fig. 3). It is from such spots that rotting occurs in the field and in transit.

Symptoms of anthracnose may be confused with those of several other diseases attacking certain genera of the Cucurbitaceae. Little difficulty should be encountered, however, in distinguishing watermelon anthracnose from watermelon wilt. The presence of leaf spots and the dying of the leaves about the crown

Fig. 2. Raised, water-soaked spots of anthracnose on mature fruit of Stone Mountain variety.

of the plants are distinguishing characteristics of anthracnose as contrasted with sudden wilting and dying of the entire runners of the plant in the case of wilt. With anthracnose the green runners near the crown of the plant appear very conspicuous in the absence of their leaves. The presence on the fruits of spots either raised and water-soaked, or sunken and decaying are also characteristic symptoms of anthracnose.

In the greenhouse *Colletotrichum lagenarium* produces damping-off on watermelons, cantaloupes, cucumbers, etc., but rarely is it responsible for this symptom in the field. *Rhizoctonia* sp. is also responsible in the greenhouse for damping-off on these hosts. Damping-off symptoms produced by these two fungi are similar but may be distinguished from each other except possibly in very young seedlings. The water-soaked portion of the hypocotyl invaded by *Colletotrichum lagenarium* is restricted to the immediate vicinity of the ground line while it extends to a distance of ½ to 1 inch above the ground line for *Rhizoctonia* sp.

Presence of pink masses of spores on the infected portions of damped-off plants may be regarded as conclusive evidence that the damping-off was caused by *Colletotrichum lagenarium.* Damping-off from *Rhizoctonia* sp. is a disease of young seedlings. It rarely attacks them after 15 days from emergence while *Colletotrichum lagenarium* may cause this symptom on greenhouse plants over a long period of time. On the leaves of watermelon in the field *C. lagenarium* causes the only serious leaf spot disease of this crop in Iowa. The Septoria leaf spot caused by *Septoria cucurbitacearum* Sacc. occurs in Iowa only rarely, and the symptoms are so inconspicuous that the disease may remain

Fig. 3. Typical symptoms of anthracnose on a fruit of Chilian, a very susceptible commercial variety. Spots are more numerous on the side of the melon near the ground (left half of fruit). The causal organism is sporulating abundantly in the sunken spots.

unnoticed. Septoria leaf spot is characterized by small, greyish white spots on the leaves near the crown of the plant. It may be recognized definitely by the presence of one to several black pycnidia in the center of each spot.

In addition to anthracnose, macrosporium and downy mildew are serious diseases of Iowa's cantaloupe crop. Generally speaking, anthracnose and downy mildew are late season diseases while macrosporium appears early in the summer. Anthracnose appears on the leaves as brown angular spots. The spots caused by *Macrosporium cucumerinum* Ell. and Ev. appear earlier in the season, are of a similar brown color but usually round in shape. Frequently concentric rings are present within the dead brown area of the spot.

The downy mildew disease caused by *Peronoplasmopara cubensis* (B. and C.) Clint. makes its appearance very late in the season on the leaves as indefinite obscure yellow spots. The yellow infected area soon turns brown and the healthy tissue surrounding it becomes yellow with further invasion. The brown spots surrounded by yellow borders $\frac{1}{16}$ to $\frac{1}{8}$ inch wide are characteristic symptoms of downy mildew. Frequently the edges of a downy mildew infected leaf will curl upward, especially if the greater portion of the leaf is attacked. The lower surface of invaded leaf areas appears dark and sooty. When preparations made from these areas are examined under the microscope, characteristic conidia and conidiophores of *P. cubensis* may be observed.

A *Macrosporium* sp. or *Alternaria* sp. is responsible, in the greenhouse, for a disease on the cotyledons of young watermelon and cantaloupe seedlings which might possibly be confused with anthracnose. Small, restricted spots are present on the cotyledons as soon as they assume their normal green color after emerging from the seed. The yellowish brown dead area in the center of

the spot is usually about 1/32 inch in diameter and surrounded by a definite yellow border. These disease spots do not enlarge in size as do anthracnose spots. The writer has not observed this disease in the field nor found it described by previous workers. This disease would not easily be confused with anthracnose.

INFECTION STUDIES

RELATION OF TEMPERATURE TO INFECTION

THE EFFECT OF THE TEMPERATURE OF THE MOIST CHAMBER ON INFECTION

Since Gardner (6) found that high temperatures were detrimental to growth of the organism, a study was made to determine the relation of temperature to infection. Study of the effect of temperature on infection was further prompted by the observation that the position occupied in the incubation chamber by the greenhouse flats containing watermelon plants inoculated with *Colletotrichum lagenarium,* was influencing the severity of infection. Those plants located at the bottom of the moist chamber were more severely infected.

Preliminary experiments showed that leaf infection did not take place in the moist chamber at a temperature of 15° C. or less, while there was severe infection at 20°. Later, anthracnose developed at the ground line on the hypocotyls of the plants held at the low temperature as a result of infection taking place after they were removed from the moist chamber. A paste made from Merko was applied before inoculation to prevent invasion of anthracnose at the ground line after removal from the moist chamber. This paste was applied to all of the plants which were used for moist chamber temperature studies.

To study the effect of temperature of the moist chamber on leaf infection, watermelon plants were inoculated and held in a moist chamber at different temperatures. Different temperatures of fair uniformity were obtained by placing moist chambers in greenhouse units, equipped with thermostatic heat controls. The experiment was conducted when it was cloudy so that the temperature from the sun would not influence the temperature inside of the moist chambers. Furthermore, a time was selected when the outside temperature was low so that the heat in the greenhouse would be supplied from the steam pipes.

A standardized hygro-thermograph was placed in each of the two moist chambers to keep continuous records of temperature and moisture. Eighteen 4-inch pots, containing one to four 23-day-old watermelon plants, were inoculated uniformly by atomizing with a suspension of *C. lagenarium.* Nine pots of the inoculated plants were placed in each of the two moist chambers and held for 16 hours. Plants were then removed from the

moist chambers and placed on the bench in a greenhouse at 20-30° C. to allow symptoms to develop. The temperature of moist chamber No. 1 was 20-26° C., and the humidity was 87-95 percent. In moist chamber No. 2 the temperature was 14-18° C., and the humidity was 88 percent. The relation of the above temperatures to infection will be found in table 1.

TABLE 1. EFFECT OF TEMPERATURE OF THE MOIST CHAMBER ON EARLY INFECTION.

Time of observation (days from inoculation)	Moist chamber No. 1 Temperature 20-26° C. Relative humidity 87-95%	Moist chamber No. 2 Temperature 14-18° C. Relative humidity 88%
8	Severe infection, plants dead	No infection
15	Severe infection, plants dead	No infection

The data in table 1 show that the plants held at the higher temperature died from leaf infection of anthracnose 8 days after inoculation, whereas no infection resulted on the plants held at the lower temperature. The second group of plants was held 15 days after inoculation, and no infection resulted. Merko paste prevented infection at the soil line. Although the relative humidity of the low temperature moist chamber was 88 percent and that of the high temperature chamber 87-95 percent, temperature is believed to be responsible for the difference between infection at 20 and 26° C. and no infection at 14-18° C.

The effect of temperature on infection 7 days after inoculation is shown in fig. 4. It is apparent that no infection resulted at or below 15° C., while severe infection occurred above 18° C.

THE EFFECT OF TEMPERATURE OF THE GREENHOUSE ON THE DEVELOPMENT OF SYMPTOMS.

As temperature of the moist chamber had been shown definitely to influence infection, it remained to determine the effect of temperature on the development of symptoms on inoculated plants. Twenty-four 4-inch pots each contained four to seven 28-day-old watermelon plants which were uniformly inoculated by atomizing with a spore suspension of *Colletotrichum lagenarium*. The inoculated plants, together with 12 non-inoculated pots of plants to serve as checks, were placed in a moist chamber for 20½ hours where the temperature was approximately 26° C. The day following inoculation was cloudy making it safe to leave the inoculated plants in the moist chamber more than 16 hours without danger of excessive temperature.

That the leaves might dry slowly, the doors of the moist chamber were opened gradually for 2½ hours before removing the plants. Plants were then removed from the moist chamber

to four greenhouse units where temperatures from 10-30° C. were maintained. Six pots of the inoculated plants were placed in each of the four greenhouse units at different temperatures to allow symptoms to develop. Three non-inoculated pots of plants were transferred from the moist chamber to each greenhouse unit to serve as checks.

Thermographs placed in each thermostatically controlled greenhouse unit showed that little difficulty was encountered in maintaining a relatively uniform temperature since the days were cloudy and the outside temperature was below freezing. The unit at 10° C. was the most uniform, the fluctuation being about 1 degree. The units at 17° C. and at 30° C. fluctuated only 2 degrees. The greatest variation was 3 degrees with the unit held at 23° C. These fluctuations may be regarded as insignificant as the temperature was, for most of the time, at the temperature listed in table 2.

TABLE 2. EFFECT OF TEMPERATURE ON THE DEVELOPMENT OF SYMPTOMS OF INOCULATED PLANTS.

Time of observation (days from inoculation)	30° C. Greenhouse unit	23° C. Greenhouse unit	17° C. Greenhouse unit	10° C. Greenhouse unit
3	Slight infection	No infection	No infection	No infection
4	Moderate infection	Slight infection	Slight infection	No infection; plants dead or dying from low temperature injury
5	Moderate infection	Moderate infection	Moderate infection	No infection; plants dead or dying from low temperature injury
8	Severe infection	Severe infection	Severe infection	No infection; plants dead or dying from low temperature injury

Results given in table 2 indicate that the development of symptoms is slightly affected by temperature. By lowering the temperature approximately 10° C., the manifestation of symptoms is retarded 24 hours. No symptoms developed at 10° C., but the plants died as a result of injury from low temperature.

HOST RANGE

Although earlier workers, as Berkeley (1) in England and Scribner (20) and Halsted (10) in this country, were of the opinion that the Colletotrichum on cucurbits was identical with that on beans, Frank (5) and Kruger (11) in Germany and Sheldon (22), Edgerton (2), Shear and Wood (21) and Gardner (6) in this country have repeatedly shown by inoculation experi-

ments that the organisms are distinct and different in their host ranges.

Colletotrichum lagenarium was first observed in 1867 on *Lagenaria vulgaris* by Passerini (14). He also recorded its occurrence on pumpkin. Later, in 1875, he found anthracnose on watermelon and cantaloupe. The disease was reported in England by Berkeley (1) as attacking cucumber. Farlow and Seymour (4) in their Host Index for 1891 listed *Colletotrichum lagenarium* as occurring on the following hosts: *Citrullus vulgaris* Schrad., *Cucumis melo* L., *C. sativus* L., *Cucurbita pepo* L. and *Cucurbita* sp. (squash). In 1884 Saccardo (19) listed *Cucumis colocynthis* as a host.

Gardner (6) added the following cucurbits to the list of susceptible hosts: *Benincasa cerifera* Savi., *Trichosanthes columbrina* Jacq., *Cucumis dipsaceus* Ehrh., *Cucumis melo* var. *dudaim* Naud., *C. melo* var. *flexuosus* Naud., *C. anguria* L., *Momordica balsamina* L. and *M. charantia* L. Gardner further reported that he was unsuccessful in obtaining infection when 6 varieties of squash, 2 varieties of pumpkin, 12 varieties of Cucurbita gourds and 2 species of Luffa were inoculated artificially with *Colletotrichum lagenarium.*

The relative response of some genera, species, sub-species and varieties of the Cucurbitaceae when inoculated with *C. lagenarium* is reported in table 3. All hosts reported were inoculated at the same time, hence their response may be regarded as comparable. In this table there appears, first, a collection of cucurbits recognized by Pangalo et al. (13) in his recent classification; second, some genera and species the susceptibility of which has been questioned and third, some new hosts.

Great differences in resistance and susceptibility of the cucurbits inoculated appeared. The genus Cucurbita was most resistant while *Citrullus fistulosus* Stocks. was most susceptible.

NEW HOSTS

From inoculations made in the greenhouse six additional species of cucurbits were found to be susceptible to *Colletotrichum lagenarium.* Since these cucurbits have not previously been recorded as susceptible, a brief description of the characteristic symptoms on each host follows:

Cucurbita texana A. Gray. Irregular light reddish brown spots ⅛ inch in diameter appeared on the leaves. These dead areas took on the appearance of oiled brown paper. The dead brown spots were surrounded by a yellow area. With age the tissue on the upper surface of the leaf bordering the spot became puckered and raised. Some of the leaves including the petioles were killed by infection. By sending out more leaves the plants finally outgrew infection.

Cucurbita foetidissima HBK. Infection similar to *C. texana.* The yellow areas surrounding the spots were very conspicuous. They sometimes were ⅛ inch in diameter.

Ibervillia tenuisecta (A. Gray) Green. Spots on the leaves were irregular in shape, ⅛-¼ inch in diameter, very light brown in color and not surrounded by water-soaked, translucent, or yellow areas. Plants may or may not be killed by anthracnose.

Apodanthera undulata Arn. Leaf spots similar to those on *Ibervillia tenuisecta,* except they were surrounded by definite water-soaked areas. No lesions occurred on the stems nor were the plants killed by the organism.

Sicyos parviflorus Willd. The leaf spots were definitely angular in shape, medium brown in color, inconspicuous and about ⅛ inch in diameter. The symptoms resembled those on *Cucumis sativus,* except they were decidedly less severe. Little damage was done to the leaves attacked or to the plant as a whole.

Luffa sp. Symptoms on this host resembled those described for *Ibervillia tenuisecta.* The organism attacked the true leaves, cotyledons and stems. The spots were medium in size and brown in color.

The writer has obtained infection with *Colletotrichum lagenarium* in the greenhouse on four varieties of pumpkin, *Cucurbita pepo* L. (*C. melopepo* L.) and two varieties of squash, *Cucurbita pepo* var. *condensa* B.; one variety of Cucurbita gourd (Japanese nest egg gourd), *C. pepo* var. *ovifera* B.; two varieties of cushaw or winter crook neck squash, *C. moschata* Duch.; two varieties of autumn or winter squash, *C. maxima* Duch. and one species of Luffa. Similarly, infection was obtained in the field when *Colletotrichum lagenarium* was inoculated to the above hosts. All of the above species, with the exception of Luffa, were very resistant. Definite symptoms appeared on the squash varieties showing that they were infected; however, these symptoms soon disappeared as the plants outgrew the effects of the disease. These results were not in accordance with Gardner's (6) findings, but since he failed to name the species of squash used, it may be that he used different species from those herein reported. Sufficiently severe symptoms developed on Luffa to raise the question of whether or not it should be classified as resistant. The species of Luffa used in these inoculations was unknown, as the seed was bought from a seed company under the name of *Luffa* sp.

As a result of this study the host range of *Colletotrichum lagenarium* has been extended to include the following susceptible Cucurbitaceae: *Apodanthera undulata, Cucurbita foetidissima, C. texana, Ibervillia tenuisecta, Luffa* sp. and *Sicyos parviflorus.*

TABLE 3. REACTION OF SOME GENERA, SPECIES, SUBSPECIES AND VARIETIES OF THE CUCURBITACEAE WHEN INOCULATED WITH *COLLETOTRICHUM LAGENARIUM*.

Host	Reaction
Citrullus colocynthis var. *insipidua* Pang.	S
Citrullus colocynthis var. *pachyrhizus* Pang.	N
Citrullus colocynthis var. *stenotomus* Pang.	N
Citrullus colocyntheides Pang.	N
Citrullus fistulosus Stocks.	S+
Cucumis microcarpus Pang.	N
Cucumis chinensis Pang.	N
Cucumis flexuosus Pang.	S
Cucumis melo sub. sp. *agrestis* var. *dulcis* Pang.	N
Cucumis melo sub. sp. *agrestis* var. *grandifolius* Pang.	N
Cucumis melo sub. sp. *agrestis* var. *dissactifolius* Pang.	R
Cucumis melo sub. sp. *agrestis* var. *typicus* Pang.	N
Cucumis melo sub. sp. *cultis* Pang.	N
Lagenaria vulgaris sub. sp. *asiatica* Pang.	N
Lagenaria vulgaris sub. sp. *africanus* Pang.	N
**Cucurbita texana* A. Gray.	R+
**Cucurbita foetidissima* HBK.	R+
Cucurbita maxima Duch.	R+
Cucurbita pepo L. var. *condensa* B.	R+
Cucurbita pepo L. var. *ovifera* B.	R+
Cucurbita moschata Duch.	R+
**Ibervillia tenuisecta* (A. Gray) Green.	N
**Apodanthera undulata* Arn.	R
**Luffa* sp.	R
Cucumis melo L. var. *inodorus* Naud.	N
Cucumis melo L. var. *reticulatus* Naud.	N
**Luffa* sp.	N
Cucumis myriocarpus Naud.	N
Cucumis africanus Lindl.	N
Cucumis naudinianus Sond.	S
**Sicyos parviflorus* Willd.	R

*New hosts.

SPECIES AND VARIETAL RESISTANCE TO *COLLETOTRICHUM LAGENARIUM* OF CULTIVATED CUCURBITS

A determination of the comparative reaction to *Colletotrichum lagenarium* of varieties and selections of *Citrullus vulgaris* (watermelon), *Cucurbita* spp. (pumpkin and squash), *Cucumis sativus* (cucumber) and *C. melo* (cantaloupe) would indicate the relative resistance or susceptibility of varieties or selections from these genera. With the view of breeding resistant varieties, collections of these plants were brought together and inoculated in the greenhouse.

WATERMELON *(CITRULLUS VULGARIS)*

The relative resistance or susceptibility to anthracnose of edible domestic and foreign watermelon varieties has received little attention from pathologists. Some varieties of citron or forage melon have long been known to be resistant to anthracnose as well as wilt, but because of the dominance of inedibility, they make undesirable resistant parents to use for crossing.

These facts led to a survey of procurable varieties of this species of melon (*Citrullus vulgaris*) with a view of finding re-

Fig. 4. Effect of moist chamber temperature on anthracnose infection. A. At 20-26° C. plants were infected and collapsed. B. At 14-18° C. no infection resulted.

sistant and desirable varieties in order to establish a breeding program for developing an anthracnose resistant commercial melon.

Seed was available from a collection made by the Iowa Agricultural Experiment Station for the wilt-resistant watermelon breeding plots. Additional seed was obtained from seed stores, growers and workers in institutions in this country and abroad and from the Division of Foreign Plant Introduction.

AMERICAN VARIETIES

EDIBLE AMERICAN WATERMELON VARIETIES

Generally speaking the term American varieties refers here to those edible varieties listed in American seed catalogs. In some cases a particular variety may be listed by different seed houses under different names.

The reaction to anthracnose was determined for the following watermelon varieties: Alabama Sweet, Angelino (white seeded), Angelino (black seeded), Apple Pie, Arikara, Baby Delight, Black Spanish, Cannon Ball, Chilian (new white seeded), Chilian (white seeded), Chilian (black seeded), Climbing (new), Coles Early, Conqueror, Cuban Queen, Dixie Queen, Duke Jones, Early Market Queen, Excel, Excel (Burrells brown seeded), Fields Jumbo, Florida Favorite, Fordhook Early, Georgia Rattlesnake, Gold Nugget, Golden Heart, Golden Honey, Golden Sweet, Grey Monarch, Halbert Honey, Harris Earliest, Hungarian Honey, Ice Cream, Iceberg, Iowa Belle, Iowa King, Irish Grey, Kansas Sweet, Kleckley Sweet, Klondike, Klondike (black seeded No. 1), Light Icing (long), Light Icing (round), Market Wonder, Mastodon Improved, Mountain Sweet, Mammoth Ironclad, New Wonder, Olds Earliest and Best, Perfection, Phenneys Early,

Phenneys Early (Improved), Pride of Georgia, Pride of Muscatine, Princess, Scarlet Wonder, Schockler, Stone Mountain, Sugar Boy, Sugar Stick, Sun Moon and Stars, Sunny Brook, Sweet Heart, Sweet Siberian, Sweet Wonder, Thurmond Grey, Tom Watson, Tom Watson (Weatherfords strain), Tom Watson (Red Heart No. 1), Wills Sugar and Winter.

Most of these 71 varieties were obtained from more than one source, hence the tests included 163 separate seed lots. Most commercial American varieties give a normal susceptible reaction typical of Kleckley Sweet. The varieties Chilian, Early Market Queen, Klondike and Winter and particularly Cannon Ball are more susceptible, while Ice Cream, Schockler and one collection of Irish Grey are slightly more resistant than Kleckley Sweet. Varieties designated as being more susceptible than Kleckley Sweet are sufficiently more susceptible to account for difference in performance under field epiphytotic conditions. The anthracnose-infected fruit shown in fig. 3 was collected from a row of Chilian watermelons growing near Stone Mountain, Improved Mastodon and Kleckley Sweet.

The Chilian variety was noticeably more susceptible, showing severe defoliation and fruit spot, while the varieties growing nearby were only slightly infected with anthracnose. The varieties Ice Cream, Schockler and one lot of Irish Grey (which gave a reaction slightly more resistant than Kleckley Sweet) do not have sufficient resistance to be of significance commercially, since under severe field epiphytotic conditions no difference in resistance between these varieties and Kleckley Sweet could be observed. It may be concluded that none of the 71 commercial edible watermelon varieties tested have sufficient resistance to anthracnose to make them of practical value in the control of this disease.

Fig. 5. Comparative resistance to *Colletotrichum lagnarium* of Africa 4 (Majorta) and Kleckley Sweet. K.—Kleckley Sweet; 25—Africa 4 (Majorta).

Fig. 6. Comparative resistance to *Colletotrichum agenarium* of Africa 8 and Kleckley Sweet. 8—Africa 8; K—Kleckley Sweet.

INEDIBLE AMERICAN VARIETIES (CITRONS AND FORAGE MELONS)

This group contains the citrons or forage melons listed by commercial seedsmen. Flesh of these varieties is coarse, hard, sour and bitter. Nothing appears in the literature concerning the relative resistance of citrons. Gardner (6) records Red Seeded Citron as a susceptible host for *Colletotrichum lagenarium* but fails to state whether it is more resistant than varieties of watermelon. Both preserving and stock citrons have been shown to be resistant to wilt, and Porter and Melhus (15) state that these varieties generally have been regarded from field observations to be resistant also to anthracnose.

Six common American varieties of citron were inoculated with the result that Red Seeded, Kansas Stock and Large Striped were more susceptible than Kleckley Sweet. Colorado Preserving, Preserving and Green Seeded were very resistant to *C. lagenarium.*

FOREIGN WATERMELON VARIETIES

One hundred sixty-five varieties of seed of edible and inedible watermelons from 15 foreign countries were inoculated and their reaction to anthracnose was determined. The countries with the number of varieties from each are given as follows: Africa, 16; Brazil, 3; China, 26; Federated Malay, 1; France, 6; Greece, 8; India, 32; Japan, 21; Mexico, 1; Peru, 2; Persia, 1; Philippines, 3; Russia, 26; Turkey, 1, and Yugoslavia 18. These foreign varieties were for the most part either as susceptible or more susceptible than Kleckley Sweet.

Five varieties obtained from Africa were highly resistant. Two of these varieties were inedible and the other three edible. Resistant plants showed only slight symptoms and continued to grow unharmed after inoculation. The comparative resistance

of Africa 4 (Majorta), one of the inedible varieties, and Kleckley Sweet is shown in fig. 5.

Similarly, the reaction of the edible variety Africa 8 is shown in fig. 6. Comparative resistance in the field for Africa 13 and Iowa Belle is shown in fig. 7.

The relative resistance to *C. lagenarium* of Africa 9-6 and Iowa Belle was observed when a naturally infected fruit of each variety, showing slight symptoms of anthracnose, was stored. After 23 days storage the fruit of Iowa Belle was destroyed by anthracnose, while under the same conditions the symptoms of anthracnose did not develop further on the fruit of Africa 9-6. Isolations made from the small, light-colored infection spots visible on the blossom end of the fruit of 9-6 gave a pure pathogenic culture of *C. lagenarium,* revealing that the causal organism was present but had failed to develop. The edible varieties, Africa 8, 9 and 13, were sufficiently resistant to form excellent material for foundation stock for breeding purposes.

SELECTIONS FROM EDIBLE AMERICAN WATERMELON VARIETIES

Porter and Melhus (15), in the process of isolating wilt resistant strains of watermelons by selection within commercial varieties, saved seed from melons maturing on living vines. Since important wilt resistant varieties have been isolated from these mass selections, it seemed desirable to make a study of these selections on the chance that varieties resistant to anthracnose might also be found.

Fig. 7. Field behavior of Africa 13 and Iowa Belle. The anthracnose resistant Africa 13 is in the section in the foreground of the center row. The anthracnose susceptible Iowa Belle is in the second section of the same row.

KLECKLEY SWEET

The largest number of selections available was from the Kleckley Sweet variety, since it was the most popular commercial variety when the mass selections were made. Of the 407 selections from Kleckley Sweet, 11 selections were more resistant and 1 more susceptible than the norm (commercial Kleckley Sweet). The resistance of these 11 selections, like that recorded for the commercial varieties, was only slight and could be regarded as of no commercial value.

CONQUEROR

Selections from the variety Conqueror were made under conditions similar to those of the Kleckley Sweet selections. Some of these selections might possibly possess resistance to anthracnose as the Conqueror variety originated from a cross of Stock Citron x Eden, a commercial watermelon variety (Orton (12)). Some of the citrons have already been shown to be resistant to anthracnose; the only stock citron seed lot tested, however, was susceptible.

Obviously, it is not possible to know whether the Stock Citron used by Orton was susceptible or resistant to anthracnose. Of the 187 selections inoculated, 65 were found that showed slightly more resistance than Kleckley Sweet. Marked differences were present in some selections 1 to 3 days after symptoms appeared, but later the only difference that could be noted was that it took 1 to 3 days longer for anthracnose to kill these slightly more resistant selections. Inoculation studies with the selections from Conqueror revealed no strains with sufficient resistance to be of commercial significance.

CANTALOUPE *(CUCUMIS MELO)*

Anthracnose is a serious menace to successful cantaloupe production. In seasons when there is an abundance of moisture, anthracnose and other leaf diseases may be the limiting factors in the production of this crop. This study was undertaken to see if resistance to anthracnose could be found among commercial varieties, mass selections or foreign varieties of cantaloupe (*Cucumis melo*).

Studies were made to determine the relative susceptibility to *Colletotrichum lagenarium* of a collection of standard cantaloupe varieties. Seed of the commercial varieties was obtained from a seed house which carried a large number of varieties. The seed of mass selections resulted from a chance hybrid selected from Honey Ball (presumably Hales Best was the other parent). This seed was available as a result of the cantaloupe breeding program of the Botany and Plant Pathology Section. Seed of the foreign varieties was obtained from the Division of Foreign Plant Introduction.

A preliminary inoculation study showed that watermelon seedlings could not be used as a standard for determining the reaction of cantaloupe since they died too rapidly when grown in the same pot with cantaloupe plants. This preliminary study showed further that a bulk collection of seed of the Hales Best variety gave a reaction comparable to other susceptible varieties. Therefore, this variety was used as the norm or standard for comparing the relative susceptibility of the cantaloupe varieties. Reaction of the cantaloupe varieties to anthracnose is based on inoculations in both the field and greenhouses.

In the greenhouse the seedlings of watermelon were definitely more susceptible to anthracnose than those of cantaloupe. Similarly, defoliation was more severe in the field on the watermelons growing in the same row with the cantaloupe varieties and inoculated in the same way. During the season in which these observations were made, there were no epiphytotics of leaf disease other than anthracnose. Under both greenhouse and field conditions the sub-species *inodorus,* in which are included the Cassaba melons, was more susceptible than the sub-species *reticulatus.* Differences in resistance which could be noted either in the field or greenhouse were too slight to be regarded as commercially significant. Hearts of Gold was the only 1 of the 32 commercial varieties to have slight resistance in the field. The 26 foreign varieties, originating from Chile, China, Morocco, Persia and Turkestan, were all susceptible.

Of the 81 mass selections inoculated in the greenhouse, six were slightly resistant, and nine were very susceptible.

CUCUMBER *(CUCUMIS SATIVUS)*

No extensive study of the response to anthracnose of cucumber varieties has been made by the writer. Seed of a number of commercial varieties was obtained at the time of making the seed collection of cantaloupe varieties. Cucumber varieties were planted in the field in a portion of the same rows with watermelon selections to be inoculated with *Colletotrichum lagenarium.*

The classification of cucumber varieties according to their susceptibility or resistance to anthracnose is based on general observations and a comparison of the severity of the disease soon after symptoms appeared and again late in the season. Only slight differences in susceptibility could be noted among the 18 cucumber varieties. Chinese Long and Serpent were highly susceptible while a number of varieties were slightly resistant. The variety Lemon, like some other varieties, was slightly resistant to leaf infection, but in addition, its vines (runners) remained green and functional late in the season, even after anthracnose had caused almost complete defoliation. By this time anthracnose had killed the vines of the other varieties.

A B

Fig. 8. Relative resistance to *Colletotrichum lagenarium* of two cucumber varieties. A—Chinese Long; B—Improved White Spine.

The relative susceptibility of Chinese Long and resistance of Improved White Spine (Heinz Special Pickling) was further demonstrated by greenhouse inoculations (fig. 8).

A variety of West Indian Gherkin, *Cucumis anguria* L., a close relative of *Cucumis sativus*, was included in the field trial and found slightly resistant, although no more resistant than a number of cucumber varieties.

The varieties of cucumber reported gave little promise as breeding stock for the development of a resistant commercial variety because of lack of differences in response to anthracnose.

Gardner (6) found two cucumber varieties, Early Russian and Giant Peru, which failed to become infected when inoculated with *Colletotrichum lagenarium*. He intimated that these varieties were as resistant to anthracnose as *Cucurbita* spp., but made no comment concerning their commercial possibilities.

PUMPKIN AND SQUASH (*CUCURBITA* SPP.)

Twenty-one varieties of *Cucurbita pepo*, *C. moschata* and *C. maxima* were inoculated in the greenhouse and in the field, with methods similar to those described for commercial varieties of *Cucumis melo*. Watermelon plants instead of cantaloupe were used as a standard for comparing the relative susceptibility. No difference in resistance or susceptibility was found for any of these 21 varieties of pumpkin and squash. In comparison with all other cucurbits inoculated, the genus Cucurbita was decidedly the most resistant.

BREEDING WATERMELONS RESISTANT TO ANTHRACNOSE AND WILT

PRODUCTION OF SUITABLE COMMERCIAL STRAINS

Seed of the anthracnose resistant selections Africa 8, Africa 9 and Africa 13 was received from the Rev. Rush F. Wagner, Old Umtali Mission, Umtali, South Africa. The packets of seed when received were labeled with the following descriptions: Africa 8, R and L, sweet, red flesh; Africa 9, white or yellow flesh, pale green melon; Africa 13, sweet, white or yellow flesh, shape nearly spherical.

The seed was divided and a part was taken to the field at Conesville for planting and observation on resistance to wilt. The remainder was grown in duplicate pots, five seeds per pot, in the greenhouse. Although Africa 8, 9 and 13 were very susceptible to wilt under field conditions, they were highly resistant to anthracnose when inoculated in the greenhouse.

Obviously, this resistance to anthracnose was the most valuable characteristic, although it was significant that the seed and leaf characters of these varieties were similar to those of commercial varieties. Promise of sweet flesh for Africa 13 and sweet as well as red flesh for Africa 8 was a further point of merit in their favor. These selections were used, therefore, as foundation anthracnose resistant stock for the breeding of varieties resistant to anthracnose and wilt.

Plants from the greenhouse inoculations were repotted, with each plant in a 4-inch pot and after 2 weeks, after recovery from repotting injuries, they were taken to Conesville and transplanted to fields relatively free from wilt. For breeding material the plants in the field were regarded as individuals until it could be determined whether they were homozygous or heterozygous for various horticultural characters. Hence, the individual plants were designated as: Africa 8-1, 8-2, etc., Africa 9-1, 9-2, etc., and Africa 13-1, 13-2, etc. Cross and self-pollinations were made on these plants.

Notes taken at the time of harvest on the melons from the individual plants of the African selections showed that each selection produced several types of melons indicating that they were heterozygous for certain horticultural characters. The selection of the crosses for use in future breeding was based partly on the notes taken on the fruits of the individual African selections. Fruits were small when compared with our commercial watermelon varieties, as they weighed from 10 to 15 pounds. Shape of the fruits of Africa 8 and Africa 13 was round, while that for Africa 9 was round or oblong. Rind color was either solid light or dark green, or light green with dark stripes. Flesh of Africa 8-1 and Africa 8-5 was red, while that

of the other fruits was yellow-white. Texture of the flesh in all cases was flaccid rather than crisp. All of the African selections were homozygous for flesh texture, edibility and resistance to anthracnose. Africa 8-5 also was apparently homozygous for red flesh color.

Crosses were made in the field in 1932 from many of the individual plants of Africa 8, Africa 9 and Africa 13 to Iowa Belle, Iowa King and a few miscellaneous varieties. These crosses brought into the breeding, anthracnose resistance, wilt susceptibility, small fruit and flaccid flesh from the African parent, and anthracnose susceptibility, wilt resistance, large fruit and crisp flesh from the Iowa varieties.

The development of a desirable commercial melon from these crosses necessitated selection not only for resistance to wilt and anthracnose but also for crisp flesh texture and size of fruit. In some of the crosses where Africa 8-4 and Africa 8-8 were used as parents it also was necessary to select for red flesh color. Most of these crosses were discarded in favor of those in which Africa 8-5 was used as a parent since it had red flesh, but because of earliness and quality a few crosses have been retained in which Africa 8-4 and 8-8 were used.

Some of the F_1 generation hybrids of these crosses were grown in the greenhouse during the winter of 1932-33 for the purpose of making self-pollinations and back crosses. From growing the hybrids, Africa 8-3 x Iowa Belle and Africa 8-5 x Iowa Belle 487, in the greenhouse it was learned that resistance to anthracnose, flaccid flesh texture and yellow-white flesh color were dominant. In the greenhouse the F_1 generation hybrids from these crosses were back crossed on the anthracnose susceptible parent (the wilt resistant parent), Iowa Belle and Iowa King. Seed obtained in the greenhouse from these back crosses and the F_1 generation seed harvested in the field in 1932 were grown in the field in 1933 on soil relatively free from wilt. It would not be possible to grow the F_1 generation hybrids except on wilt-free soil, since the work of Orton (12) and Porter and Melhus (15) indicated that resistance to wilt was inherited as a recessive character. For comparison, the F_1 generation hybrids were grown in the same row between their two parents.

An anthracnose epiphytotic was initiated early in the season by spraying the plants in the entire field with a suspension of *Colletotrichum lagenarium*. The suspension of spores was applied late in the afternoon on several successive days during the latter part of June. By Sept. 1 the anthracnose epiphytotic had become so severe as to kill all of the plants of the susceptible varieties. Field observations confirmed those made in the greenhouse that resistance to anthracnose was dominant in the first generation (fig. 9).

Fig 9. The first generation hybrid from a cross of Africa 8-5 x Iowa Belle. Compare with the susceptible Iowa Belle parent in the second section of the same row.

The greenhouse has proved a distinct advantage for making rapid progress with the breeding program. Since 1932 it has been possible to grow three generations in the greenhouse in addition to those grown in the field. The segregating plants were grown in pots in the greenhouse, inoculated and the anthracnose resistant segregates were then transplanted to wilt infested soil to eliminate the wilt susceptible individuals. The field epiphytotic of anthracnose and wilt were sufficiently severe to eliminate susceptible selections and susceptible individual plants within a selection.

Frequently some of the selections to be grown in the field were first grown in pots in the greenhouse and inoculated to remove the anthracnose susceptible segregates. The plants were then transplanted to wilt infested soil in the field. This procedure selected the anthracnose resistant individuals, without the necessity of creating, early in the season, an artificial anthracnose epiphytotic in the field. Some homozygous selections resistant to both anthracnose and wilt have been isolated from the Iowa Belle-Africa crosses by using the above methods (fig 10). The crosses using Iowa King as one of the parents were discarded since Iowa King does not have sufficient resistance to withstand a severe epiphytotic of wilt.

Since the market demands a watermelon of higher quality

Fig. 10. Selections highly resistant to anthracnose and wilt (1935). (Contrast with fig. 11.)

than Iowa Belle, and obviously a variety would not be produced from these crosses with higher quality, some of the most promising of the anthracnose-wilt resistant segregates were crossed on several wilt resistant strains of superior quality and more intense flesh color.

Russia 15, Yugoslavia-Iowa Belle hybrids, California wilt resistant Klondike, Iowa Klondike, wilt resistant Stone Mountain and Improved Kleckley Sweet No. 6 were some of the wilt resistant strains used for crossing to improve the quality of the anthracnose-wilt resistant selection. Japan 4, an early variety which is susceptible to both wilt and anthracnose, also was used for crossing to introduce earliness into these crosses. Some very promising selections have been made from these crosses, but none is as yet homozygous (fig. 10). The importance of anthracnose resistance is shown in fig. 12.

INHERITANCE OF RESISTANCE TO ANTHRACNOSE

The fact that Africa 8, Africa 9 and Africa 13 were resistant to a degree that no plants were killed when commercial varieties were 100 percent killed when inoculated, suggested that these varieties might be suitable for studying the genetical relationship between resistance and susceptibility. This possibility was further emphasized when these varieties were found to cross readily without the production of mosaic-like susceptible segre-

Fig. 11. Wilt resistant selections that are very susceptible to anthracnose (1935).

gates (Porter and Melhus, 15), sterile or other aberrant forms. The inheritance of resistance was studied to obtain information that might be used in the breeding program to combine anthracnose resistance with other characters.

Crosses were made in the field of Africa 8-5 x Iowa Belle 487, Africa 8-3 x Iowa Belle 476 and Africa 8-4 x Iowa Belle 494. The reciprocal was made of the first cross, Iowa Belle 487 x

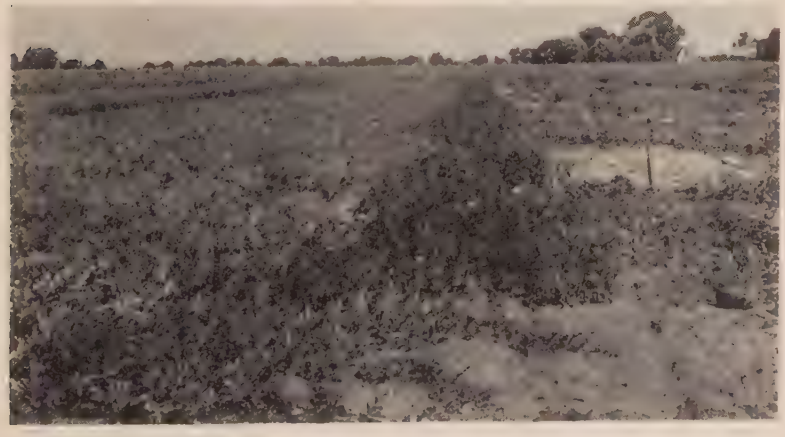

Fig. 12. Comparison of selections highly resistant to anthracnose and wilt (left of tomato row) with selections highly resistant only to wilt (right of tomato row). (1935).

Africa 8-5. Both parents, the F_1 and F_2 from the crosses and the F_1 back-cross generation plants listed in table 4 were grown in the greenhouse and inoculated with *Colletotrichum lagenarium*. Results of these studies are given in table 4.

Resistance was dominant to susceptibility (fig. 9), and segregation in the F_2 and in the F_1 back-cross generation plants proved that only a single factor pair for resistance and susceptibility was involved.

TABLE 4. INHERITANCE OF RESISTANCE TO ANTHRACNOSE IN WATERMELONS.

	Actual Ratio		Expected Ratio	
	Resistant	Susceptible	Resistant	Susceptible
Africa 8-5 x Iowa Belle 487				
F_1 Resistance dominant				
F_2				
129-S1	122	44	124	42
129-S3	146	50	147	49
F_1 Back crossed on susceptible parent				
397 x 129-1	180	189	184	185
F_1 Back crossed on resistant parent				
39 x 129-2	152	0	152	0
Iowa Belle 487 x Africa 8-5				
F_1 Resistance dominant				
F_2				
130-S1	339	101	330	110
130-S2	127	45	129	43
F_1 Back crossed on susceptible parent				
397 x 130-1	77	78	77	78
397 x 130-2	164	151	157	158
Africa 8-3 x Iowa Belle 476				
F_1 Resistance dominant				
F_2				
116-S3	216	64	210	70
F_1 Back crossed on susceptible parent				
393 x 116-1	137	138	137	138
F_1 Back crossed on resistant parent				
37 x 116-2	235	0	235	0
Africa 8-4 x Iowa Belle 476				
F_1 Resistance dominant				
F_2				
121-S4	254	93	261	87
F_1 Back crossed on susceptible parent				
121-398	110	100	105	105

DISCUSSION

In this study on the parasitism of Colletotrichum a large number of genera of the Cucurbitaceae have been shown to be susceptible. All genera studied within the family are susceptible. Great differences in susceptibility were noted among the various species and varieties. It was not possible, however, to arrange the genera studied according to their relative susceptibility because of the great differences in reaction among species and varieties within a single genus. From the standpoint of relative susceptibility Cucurbita may be said to occupy the position of

the most resistant genus studied, as all species and varieties inoculated were very resistant.

The genus Citrullus apparently should be placed among the most susceptible genera of the Cucurbitaceae, as most species and varieties are attacked severely by *Colletotrichum lagenarium*. Although this genus, as a whole, may be regarded as very susceptible, it does possess certain citrons and edible African watermelons (Africa 8, 9 and 13) the resistance of which is comparable to that of Cucurbita. Because of this fact Citrullus seems to be a unique genus among the Cucurbitaceae insofar as resistance to anthracnose is concerned.

No species or varieties of Cucumis (cucumber and cantaloupe) were found with any appreciable resistance to anthracnose. Gardner reported two varieties of cucumbers which were not attacked by the anthracnose organism. There may be a possibility, however, that these two varieties escaped disease rather than having resistance. No doubt Gardner would have pointed out the possibilities of these two cucumber varieties for use in breeding resistant strains had he considered them sufficiently resistant to use as parental stocks.

Resistant types of Citrullus as citrons and edible African watermelons (Africa 8, 9 and 13) easily could have developed in Africa, the home of the watermelon, where anthracnose probably has been a disease of long standing. Lack of resistance in Cucumis, particularly the cantaloupe, might be accounted for by the absence of anthracnose in Asia (Persia) where the cantaloupe has been grown for centuries.

The discovery of anthracnose resistant edible watermelons reported in this paper has already proved to be a distinct stimulus in the development of commercial watermelon strains resistant to the disease. Since it has been shown here that resistance to anthracnose is inherited on the basis of a single genetic factor, it should be relatively easy for plant breeders to develop anthracnose resistant strains of the important watermelon varieties.

As a result of the intensive breeding program, edible strains have been produced that are resistant to both wilt and anthracnose (fig. 10).

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